

Lunar Prospector Simulation

Teacher's Guide





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Acknowledgments

This curriculum supplement module was developed by the External Affairs Office and scientific community at NASA Ames Research Center, Moffett Field, California.

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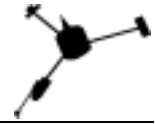
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Draft version December, 1997



Introduction

Lunar Prospector will launch to the Moon, Jan 5th, 1998. Within a month it will begin returning answers to long-standing questions about the Moon, its resources, its structure and its origins. Prospector will accomplish these goals during its primary one-year polar orbiting mission. Using a complement of five instruments, the mission will yield important science results at an unprecedented low cost. The first and most exciting data returned will answer the question first raised in the early seventies and underscored by the 1994 Clementine mission: Is there water in the form of ice in some polar craters? The significance of this information for further exploration of the Moon and future utilization of Moon resources is great. Besides water, Lunar Prospector will look for other natural resources, such as minerals and gases, that could be used to build and sustain a future human lunar base or in manufacturing fuel for launching spacecraft from the Moon to the rest of the Solar System.

Prospector is a NASA Discovery Mission. This new kind of mission places an emphasis on science and "Faster, Better, Cheaper" mission design and development. Lunar Prospector exemplifies these goals. It is a small, spin-stabilized craft that uses flight-qualified, modern technologies and instrumentation to ensure results and minimize risk. The design is simple: a small, graphite-epoxy drum (1.4m x 1.2m) with surface mounted solar cells and three 2.5m masts which carry the instruments and isolate them from the bus.

Background information provided by Alison Davis, et. al.



Lunar Prospector Simulation

The Lunar Prospector Simulation is the centerpiece of this teacher's guide. It is available through the Internet at "<http://www.exploringspace.arc.nasa.gov>", check this site also for CD-ROM availability. The Simulation is about 200 K and can be downloaded in approximately 5 minutes using a 14.4 baud modem. It can be accessed from IBM or Mac computers using either Netscape or Internet Explorer browsers. To use the software a Shockwave viewer will also need to be downloaded from Macromedia's Website (link provided).

The Simulation is an entertaining and educational game without this corresponding Teacher's Guide but with it you and your students will be able to extend your knowledge of the Moon, scientific spacecraft, and the structure of missions to other bodies within our solar system.

The Lunar Prospector Simulation



Structure and Navigation

The Lunar Prospector Simulation is organized into three informational sections and one interactive game. Clicking on the red triangle in the lower left corner of the screen will raise the navigation menu containing four choices: **The Moon**, **The Lunar Prospector**, **The Mission Briefing**, and **The Mission**. Select a section by moving your cursor over the menu and clicking when the section you want to transfer to is highlighted.



Screen one of **The Moon** section



If you travel top-to-bottom through the navigation menu **The Moon** is the first section you will find. This section contains two screens with basic information about the Moon. The arrows along the lower edge of the screen will move you between the pages.

First screen of the **Lunar Prospector** section



Moving your cursor over each component on the left of the screen will cause a description of that component to appear in the text area at the right. Click on component 2, the Shroud, to get further information on the elements contained within it. Click on component 4 for detailed information about the six scientific instruments and two subsystems aboard the Lunar Prospector.



The Mission Briefing



The **Mission Briefing** contains information about the four steps of **The Mission** game. At each step--launch, correction phases 1 and 2, and Lunar Orbit Insertion--choices must be made about the mission. Placing your cursor over the step you want to know more about will display related information in the text area on the right.

The Mission



The Mission is the interactive game section of the Lunar Prospector Simulation. During **The Mission** students have a chance to synthesize what they have learned from the previous sections in order to complete a successful orbital insertion around the Moon. As illustrated in the **Mission Briefing** section, there are four important decision points--launch, correction phases 1 and 2, and lunar orbit insertion. At each decision point, the students will select one of four options. For instance, there are four launch times to choose from.



Set orientation using Pointing Control Panel



During the correction phases, the craft can be pointed in one of four directions to optimize battery charge and communication. Finally there are four options to select from for Lunar Orbit Insertion. With the exception of launch, each choice must be made within a brief time period. Failing to make a decision in the time allotted can be disastrous for that particular mission but not for the student. This game is intended for the kind of repeated play needed to build intuitive knowledge of orbital dynamics and some of the complexities of this kind of mission. Lack of success on one Moon shot is an invitation to return to explore previous sections for more information, or to simply restart the game itself.

A final note about The Lunar Prospector Simulation software: this is a highly simplified version of the Lunar Prospector mission. For instance the craft is spin-stabilized and rotates constantly once it leaves Earth orbit. The real Lunar Prospector will need more than two course corrections plus it takes several readjustments to get the Prospector into perfect polar orbit. Simple or not, the Lunar Prospector Simulation is a stimulating opportunity for students to have a taste of space exploration without all the expense.



How to Use this Guide

This Lunar Prospector Simulation Teacher's Guide supports the Lunar Prospector Simulation software program. It is available as a PDF file through the Internet at "<http://www.exploringspace.arc.nasa.gov>", check this site also for CD-ROM availability. You will need to download the Adobe Acrobat Reader to view and print this document (link provided). The Student Resource Archive is also a PDF file and is available at the same location.

Audience

This guide is designed for use with fourth through eight grade students. All activities can be implemented with those grades, however teachers of younger students may want to take advantage of the "Optional" suggestions included in several of the activities. The Optional suggestions are for adapting activities to suit younger or less experienced students.

Preparation

This unit is intended to stand alone--all the resources you will need are included in the Teacher's Guide and Student Resource Archive. However, you can add depth and richness by collecting books, video tapes, posters, software, and models to supplement the activities described here. The Resource section has lists of possible locations for finding such additions.

Computer Use

The activities described in this guide call for several kinds of computer use. Several require the teacher to demonstrate how to use the Lunar Prospector Simulation software and access the Student Resource Archive. All activities require students to be involved in using the computer to access the Lunar Prospector Simulation software or research a topic in the Student Resource Archive. Ideally the students would have access to both a computer lab and regular classroom. However all activities can be adapted to suit an in-class computer center that has several computers.



Activity One - Why the Moon?

Introduction

In this activity you will have a chance to discover what your students already know about the Moon. You will also introduce Lunar Prospector, the Lunar Prospector Simulation, and the activities that support it. Finally you will give your students a sense of direction and excitement about the upcoming unit.

Objectives

- The students will be able to play The Mission game (though not successfully).
- The students will be able to create a cut-away view of the Moon with parts labeled.

Key Details

Depending on your students' abilities and prior knowledge this activity should take:

10-20 minutes introduction and discussion

2-5 minutes for The Mission

10-20 minutes for research

20-50 minutes for illustration of Moon

Total 42-95 minutes

Supplies

- 2 pieces of chart paper, markers, masking tape
- scratch paper
- drawing paper, colored pens or pencils
- student worksheet *Student Directions for Drawing the Moon*
- Lunar Prospector Simulation CD-ROM or browser + Internet access

Equipment

- method of displaying computer screen output (LCD display and Overhead Projector, large monitor, or projector)
- computers (center or lab set up)
- Optional: 5 to 7 foot string or jump rope



Preparation -- The Day Before

Read through the briefings in the Lunar Prospector Simulation. Play The Mission several times to get an understanding of the options and possibilities.

These settings will ensure success:

Launch time: 1 pm

orbital correction burn 1: antenna down

orbital correction burn 2: antenna down

lunar orbit insertion burn: 30 minutes

Install from CD or bookmark Exploring Space for the Lunar Prospector Simulation and Student Resource Archive on your center or lab computers, and test. Collect supplies and equipment. Make enough copies of the *Student Directions for Drawing the Moon* page for each student or team of students to have one.

Preparation -- Before the Activity

Attach two sheets of chart paper to the chalkboard with masking tape. Have pens handy. Set up computer and monitor or screen so the whole class can see it.

Description of Activity

1. Introduce the unit by displaying The Mission part of the Lunar Prospector Simulation. Have students¹ make suggestions about control panel settings. Avoid making the choices that create a successful mission (see Preparation section above).

The Mission game



¹ Boys will be much more comfortable contributing to this part of the activity, be sure girls have a voice too.

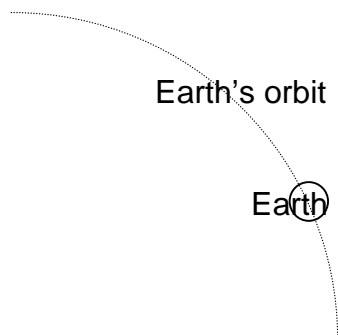


2. Point out that more information and planning is needed to fly a successful mission to the Moon. Ask students to share what they already know about the Moon and how to get there. Record these ideas on one of the chart papers. (Keep both chart papers until the end of the unit.) Make no attempt to correct naive conceptions at this point--students will have a chance to do it themselves over the course of the unit.
3. Explain that the students will be learning more about the Moon in this activity. To do this they will do some research and create a cut-away illustration of the Moon. Instruct the students to use the Student Resource Archive to find out about the features and composition of the Moon--its surface, crust and core. Project your computer screen output and demonstrate how to access the Lunar Prospector CD or Website and locate the Student Resource Archive. Hand out directions and supplies and allow time for students to research and draw.
4. Have students brainstorm why scientists would want more information about the Moon. Record their ideas on the second chart paper. After the brainstorming session winds down ask the students why they think the craft is named Lunar Prospector. Tell the students that scientists consider the Moon to be a good location for observing the Earth as well as launching solar system and space exploration missions. If the Moon can also be mined for necessities like water, nitrogen, carbon monoxide, and carbon dioxide it would be an ideal extraterrestrial human outpost.



5. Explain that the goal of this unit will be to get the Lunar Prospector into polar orbit around the Moon. They will have a chance to learn more about the craft and about how to complete The Mission successfully. Dramatize the following or review it in lecture format.

Use chalk to sketch an arc representing the path of the Earth around the Sun.

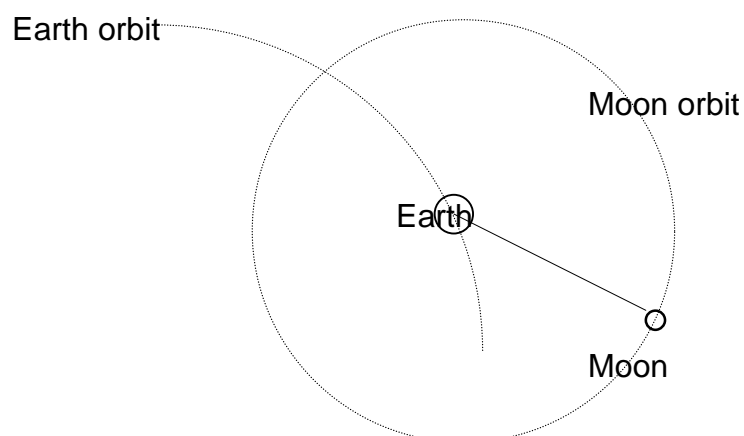


Have a student representing the Earth move slowly along that path. Explain that the Earth takes 365 days to make a complete orbit around the Sun. Ask your students to estimate how fast the Earth would have to move to complete that orbit. Have them decide how big each of the Earth's steps should be and how many steps represent one 24-hour day. Add the Moon by having a second student, representing the Moon, hold one end of a 5 to 7 foot string or jump rope and the student representing the Earth hold the other end. The Moon orbits the Earth by keeping the rope taut as it moves around the Earth at the same time as the Earth moves along its orbit. Halt the demonstration and explain that the Moon takes about 27 days to go around the Earth. Ask your students to choose appropriate speed of travel for the Moon and how many steps represent one Earth day. (For instance the Earth might take heel-to-toe steps while the Moon takes longer steps².) Ask the Earth and Moon students to step aside and use the chalk to mark where they stopped. Challenge your students to draw a flight path for a space craft that travels from the Earth to the Moon in about five days.

² The speed of travel depends on the size of the arc you have drawn and the radius of the Moon's orbit. It is OK to approximate the speeds of both bodies so long as it remains consistent throughout the demonstration.



Modeling the Earth/Moon system



Have the Earth and Moon students resume their positions and travel for 5 days. How accurate was the path of the craft? Discuss or try again as necessary to make the point that it is complex issue involving the motion of the Earth and Moon as well as the speed of the spacecraft. What changes would need to be made to the path of the craft if it took the 2 days to reach the Moon? What if it took 11 days?

Assessment

In this activity students demonstrate their knowledge by contributing to the class discussions and by their labeled illustration of the Moon. Use the illustration of the Moon to assess what each student learned in this activity. Depending on the age and ability of your students they should have created a clear drawing and labeled the following features:

maria (filled with volcanic flows)
highlands
craters
volcanic flows
ice deep in polar craters

surface (composed of KREEP)
mantle
metallic core

Some student may choose to name specific features or locate the Apollo landing sites.



Follow Up Activities

- Build a scale, both distance and size, model of the Earth/Moon system.
- Do phases of the Moon activities.
- Model cratering using rocks and wet sand.



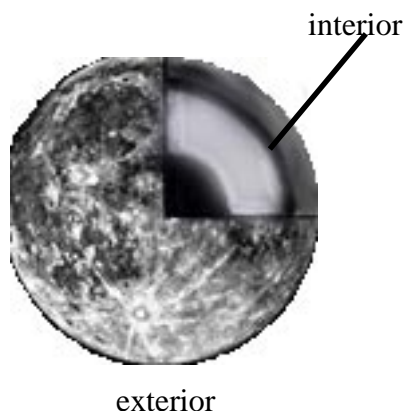
Student Directions for Drawing the Moon

1. Your assignment is to create a drawing of the Moon that shows the surface and the interior. First you will need to learn more about the Moon. It will be helpful to know:

- what the surface features look like
- what the surface is made up of
- size of the core and mantle
- what the core and mantle are made up of
- possible locations of water ice

Use the Student Resource Archive or the resources your teacher provides to learn more about the Moon.

2. Choose a method of drawing a cut-away view. Artists do this many ways, one is to show a pie slice which reveals the inside of the Moon.



3. Use scratch paper to sketch a draft of your illustration of the Moon. When you are ready get drawing supplies from your teacher and draw a cut-away view of the Moon.

4. Label the important parts. Add your name and the date and hand in to your teacher.



Activity Two - Become a Research Specialist

Introduction

In this activity students have a chance to model how scientific research teams operate. They will gain an overall understanding of the Lunar Prospector space craft as well as specific knowledge about one of the scientific instruments.

Objectives

- The students will be able to state some basic information about the Lunar Prospector mission.
- Each student will be able to demonstrate knowledge of a specific scientific instrument.

Key Details

Depending on your students' abilities and prior knowledge this activity should take:

5 minutes introduction and explanation

2-5 minutes demonstration

5-15 minutes for using software

15-30 minutes for research

15-25 minutes for the Lunar Prospector Game Show

Total 42-80 minutes

Supplies

- Student Information page *Student Team Information Page -- Scientific Instruments*
- Student Information page *Student Information Page -- Scientific Instruments Study Sheet*
- Lunar Prospector CD-ROM or browser + Internet access
- One copy *Teacher Page - Lunar Prospector Game Show Cards*
- pad of paper and marker for each team

Equipment

- display for computer output (LCD panel and Overhead Projector, large monitor, projector)
- computers (center or lab set up) with Lunar Prospector CD installed or Website bookmarked



Preparation -- The Day Before

Make enough copies of the *Student Team Information Page -- Scientific Instruments* for each team to have one. Make enough copies of the *Student Information Page -- Scientific Instruments Study Sheet* for each student to have one. Organize your students into teams of 5 each. If you chose to assign scientific instruments to specific students, fill out the blanks on the *Student Team Information Page -- Scientific Instruments*. In your computer lab or center, check the Lunar Prospector Simulation on CD or Exploring Space bookmark to be sure they are functioning.

Preparation -- Before the Activity

Draw a 6x7 table on the chalkboard and fill out as shown below.

Optional (see number 5 below): draw a 6x5 or a 6x6 table that extends down to 400 and 500 points respectively.

Lunar Prospector Game Show board

General Lunar Prospector	Neutron Spectrometer	Gamma Ray Spectrometer	Alpha Particle Spectrometer	Magnetometer and Electron Reflectometer	Doppler Gravity Experiment
100	100	100	100	100	100
200	200	200	200	200	200
300	300	300	300	300	300
400	400	400	400	400	400
500	500	500	500	500	500
600	600	600	600	600	600

Description of Activity

1. Briefly review the previous activity and introduce the current one. Students had a chance to see The Mission and get some idea of the complexity of the task--send the craft to the Moon and put it into polar orbit. In an attempt to figure out why scientists wanted to know more about the Moon, students studied the Moon. In this activity they will focus the Lunar Prospector itself.
2. Explain that students will be working in research teams of 5 people. Every team member will learn about the basic components of the craft--thrusters, antenna, battery, and solar panels. Each member will specialize one of the scientific instruments--Neutron Spectrometer, Gamma Ray Spectrometer,



Alpha Particle Spectrometer, Magnetometer/Electron Reflectometer, and the Doppler Gravity Experiment. To become specialists, students will need to research their instrument.

3. Project your computer screen output and demonstrate how to access the Lunar Prospector CD or Website and locate both the Lunar Prospector Simulation and the Student Resource Archive. To gain knowledge of the general aspects of the Lunar Prospector spacecraft, have students turn to their computers and go through the Lunar Prospector Simulation focusing on the informative parts. (You will need to set boundaries about how many times they can play The Mission at the end.)
4. When students have had a chance to review the Lunar Prospector Simulation and play The Mission, read off student teams and hand out the *Student Team Information Page -- Scientific Instruments*. If you have not assigned students specific instruments have the teams do that first. Instruct them to use the Student Resource Archive, and any other resources you are able to provide, to research their instrument. The *Student Information Page -- Scientific Instrument Study Sheet* will provide guidance if necessary.
5. After students have had time to research their instruments, cluster the teams in front of game table and introduce them to the Lunar Prospector Game Show.

Guidelines for Lunar Prospector Game Show

The Lunar Prospector Game Show is played in teams. To begin each round, a category and point category are chosen by a team from the game table. Each cell of the table has a corresponding question that the teacher reads aloud from the *Teacher's Key -- Lunar Prospector Game Show Cards*. The teams are given between 30 and 60 seconds, depending on age and ability, to record their answer on a pad of paper. At the end of the time period, have all teams display their answer. Each team with a correct answer earns the number of points indicated. Team members, a special recorder, or the teacher can be responsible for keeping a running total of team scores.

Check for comprehension, when you feel that everyone understands the rules of the game, hand out pads of paper and markers. Play The Lunar Prospector Game Show.



As the game progresses, have a student cross off each cell as it is selected.

Optional: Younger students may struggle with the complexities of describing how instruments work, in this case simplify the game by leaving off the last one or two categories, those associated with 500 and 600 points.

6. Wrap up by totaling scores and congratulating all participants. Lead a discussion about the advantages of team work. Ask students to explain why scientists might work in teams to accomplish difficult tasks like the Lunar Prospector Mission.

Assessment

In this activity students demonstrated their knowledge by participating in the Lunar Prospector Game Show. If observing them is not enough to assess what they learned, or, if you feel they need additional reinforcement, make extra copies of the teacher's key page for this activity and cut the questions and answers apart. Have your students glue or tape them to a blank page in appropriate order, i.e., questions under the correct categories and answers with the proper questions.

Follow Up Activities

- Have student draw and label the Lunar Prospector.
- Build a model of the Lunar Prospector. See resource section for information on model kits available through the NASA Teacher Resource Centers.
- Have the specialists work in teams to give a press conference about the Lunar Prospector to another class.



Student Team Information Page -- Scientific Instruments

You are now members of the Lunar Prospector research team. Like the team NASA put together for the mission, each of you will specialize in one of the following scientific instruments that are aboard the Lunar Prospector. You will need to use the Lunar Prospector Simulation and the Student Resource Archive to become a specialist in your field.

Neutron Spectrometer--Specialist's name: _____

The Neutron Spectrometer searches for water ice on the Moon by detecting the hydrogen atoms in water. The deep, permanently shadowed craters near the Moon's poles seem to be the best places to look for water.

Gamma Ray Spectrometer--Specialist's name: _____

The Gamma Ray Spectrometer will map the abundance of 10 elements on the Moon's surface: thorium, potassium, uranium, iron, oxygen, silicon, aluminum, calcium, magnesium, and titanium.

Alpha Particle Spectrometer--Specialist's name: _____

The Alpha Particle Spectrometer will detect radioactive radon gas that might be leaking out from the lunar interior. Scientists expect to find elements such as radon, nitrogen, and carbon dioxide. Such gasses, which can be released by Moon quakes and volcanic activity, will provide information on how active the Moon is.

Magnetometer/Electron Reflectometer--Specialist's name: _____

The Magnetometer/Electron Reflectometer will measure the strength of the Moon's magnetic field at two locations: near the spacecraft and at the lunar surface. It will be able to detect tiny variations in the Moon's magnetic field and help determine where these are caused by surface features as well as to what extent they result from a possible magnetic core.

Doppler Gravity Experiment--Specialist's name: _____

The Lunar Prospector does not require a separate instrument for measuring the Moon's gravitational field. Instead scientists will track changes in the speed and altitude of the spacecraft by measuring the change in frequency of the Lunar Prospector's communications signal. Small variations, mapped to geographic location, will indicate if the craft is traveling over areas of higher or lower gravity. Knowing where high gravity areas are on the Moon will enable future lunar missions to use their fuel more efficiently when orbiting it.



Student Information Page Scientific Instrument Study Sheet

Your name: _____ Date: _____

Name of your scientific instrument: _____

Here are some things you might look for in researching your instrument. You may not be able to answer all of the following questions from the information that you have been given.

What is the “job” of your instrument? What elements, atoms, rays, or forces does it detect?

How would you describe what it detects?

Where will it be “looking” for those elements, atoms, rays, or forces? Where is the most likely place to locate them?

How does the instrument work?

What are the details of your instrument? (Size, weight, components, etc.)

What is its level of accuracy? What will make it more accurate?

When will its data be useful?

What will it tell scientists about the Moon?



Teacher Key - Lunar Prospector Game Show Cards

Points	General Lunar Prospector	Neutron Spectrometer (NS)	Gamma Ray Spectrometer (GRS)	Alpha Particle Spectrometer (APS)	Magnetometer and Electron Reflectometer (MAG and ER)	Doppler Gravity Experiment (DGE)
100	Q. What is the Lunar Prospector's launch vehicle? A. Athena rocket.	Q. What is the Neutron Spectrometer's job? A. To search for water ice.	Q. What is the Gamma Ray Spectrometer's job? A. To map the abundance of elements on the Moon's surface.	Q. What is the Alpha Particle Spectrometer's job ? A. To search for radon outgassing from the interior of the Moon.	Q. What is the job of the Magnetometer and the Electron Reflectometer? A. To measure magnetic field strength near the craft and at the Lunar surface.	Q. What is the job of the Doppler Gravity Experiment? A. To improve current models of the Moon's gravitational field.
200	Q. Where is the energy from the solar panels stored? A. In a solar cell-powered, rechargeable nickel-hydrogen battery.	Q. How much water can the Neutron Spectrometer detect? A. A cup of water in a cubic yard of soil.	Q. Where will most of the elements be found? A. In the youngest rocks.	Q. How much does the APS weigh? A. 4 kg (9 lbs).	Q. What previous spacecraft used similar instruments? A. The Mars Global Surveyor.	Q. What is a mascon? A. A mass concentration of gravity on the surface of a planetary body.
300	Q. What provides all the power to run the Lunar Prospector's instruments? A. The solar panels.	Q. What does the Neutron Spectrometer detect? A. Hydrogen atoms.	Q. What is a Gamma Ray? A. A very energetic photon.	Q. What is an alpha particle? A. The Nucleus of a helium atom, two protons and two neutrons bound together.	Q. Which instrument measures the magnetic fields at the Moon's surface? A. The Electron Reflectometer.	Q. How long will it take the DGE to complete a gravity map of the Moon? A. Two months.

(page 1 of 2)



400	<p>Q. What does the Trans Lunar Injection Thruster Module do?</p> <p>A. Increases the speed of the craft to boost it from Earth orbit on its trip to the Moon.</p>	<p>Q. If there is water ice on the Moon, where will the Neutron Spectrometer most likely find it?</p> <p>A. In deep, permanently shadowed craters.</p>	<p>Q. Name three or more of the elements the GRS is trying to detect</p> <p>A. Thorium, potassium, uranium, iron, oxygen, silicon, aluminum, calcium, magnesium, and titanium.</p>	<p>Q. What is the APS detector made of?</p> <p>A. 10 silicon wafers.</p>	<p>Q. Why are the ER and the MAG mounted on a boom?</p> <p>A. To isolate them from the magnetic fields generated by the instruments aboard the craft.</p>	<p>Q. When will gravity be the only force acting on the Lunar Prospector?</p> <p>A. When the thrusters are not firing.</p>
500	<p>Q. What kind of antennas are aboard the Lunar Prospector?</p> <p>A. A medium gain and an omni-directional.</p>	<p>Q. What other scientific instrument shares a boom with the NS?</p> <p>A. The Alpha Particle Spectrometer.</p>	<p>Q. What will the GRS data tell scientists?</p> <p>A. About the origins of the Lunar landscape and where useful metals are located.</p>	<p>Q. What will make locating outgassing events more precise?</p> <p>A. A lower orbit (6 miles above the surface rather than 63). Or, greater duration of the mission.</p>	<p>Q. How does the ER measure the magnetic field at the surface of the Moon?</p> <p>A. It measures the pitch angles of the electrons reflected off the surface of the Moon.</p>	<p>Q. How can the precision of the gravity data be improved?</p> <p>A. By dropping down to a closer (10 km or 6 mi.) orbit of the Moon.</p>
600	<p>Q. What does the shroud do?</p> <p>A. Protects the Lunar Prospector and the Trans Lunar Injection (TLI) motor from atmospheric forces experienced during launch.</p>	<p>Q. What is a "cool" Neutron?</p> <p>A. Neutrons that have bounced off a hydrogen atom somewhere on the Moon's surface.</p>	<p>Q. How can scientists tell what kind of atom has been detected by the GRS?</p> <p>A. By the intensity of the flash given off by the gamma ray when it strikes the crystal in the GRS.</p>	<p>Q. How can scientists tell what kind of element has been detected by the APS?</p> <p>A. The APS detects a charge that is proportional to the energy of an alpha particle. The energy level of the alpha particle indicates the element that emitted it.</p>	<p>Q. How does the MAG measure magnetic fields?</p> <p>A. By measuring the variation of the current passing through the electric coil.</p>	<p>Q. How does the DGE measure gravity?</p> <p>A. By tracking the velocity (speed) of the space craft, scientists can infer what forces are acting upon it. Or, by tracking the frequency (Doppler effect) of the craft's radio signal.</p>



Activity Three - Mission Briefing

Introduction

In this activity students will learn more about the many steps from launch to Lunar orbit insertion. Your students will also be challenged to use research, math, note-taking, and artistic skills to create a scale timeline of those events.

Objectives

- Older students will be able to research and record their findings
- Older students will be able to convert times from the Lunar Prospector Mission Timeline to total elapsed time.
- All students will be able to create a timeline to scale.

Key Details

Depending on your students' abilities and prior knowledge this activity should take:

2-5 minutes introduction
5-10 minutes demonstration
15-30 minutes for research
10-30 minutes for converting times
10-30 minutes for completing timeline
5-10 minutes for discussion

Total 47-115 minutes

Supplies

- for older students, the Student Information page *Student Directions for Creating a Lunar Prospector Mission Timeline*
- for younger students, Student Information page *Lunar Prospector Mission Timeline*
- 4 meters adding machine tape for each pair of students plus a spare for teacher demonstration
- pencils and note paper, colored pens, and a centimeter ruler per pair

Equipment

- display for computer output (LCD panel and Overhead Projector, large monitor, projector)
- computers (center or lab set up) with Lunar Prospector CD installed or Website bookmarked



Preparation -- The Day Before

Organize your students into pairs. Make enough copies of *Student Directions for Creating a Lunar Prospector Mission Timeline* for each pair of older students to have one. Or make enough copies of *Lunar Prospector Mission Timeline* for each pair of older students to have one. Find the Lunar Prospector Timeline in the Student Resource Archive and note its location. Observe the use of elapsed time along the left margin of the mission timeline and decide if your students will need extra instruction to be able to convert the times given into total elapsed times. Measure and cut adding machine tape into 4 meter lengths.

Preparation -- Before the Activity

Collect supplies.

Description of Activity

1. Briefly review the previous activity and introduce the current one. In the last activity students learned about the Lunar Prospector spacecraft, its scientific instruments, and its mission, in this activity they will learn more about the many steps from launch to Lunar orbit insertion. Finally they will create a scale timeline illustrating those steps.
2. Project your computer screen output and explain or demonstrate how to find the Lunar Prospector Timeline in the Student Resource Archive and how to record (take notes) on it. Provide instruction as necessary to support students in converting the times stated to total elapsed times.

For younger students give them a copy of the *Lunar Prospector Mission Timeline* rather than having them research and convert the time. Move on to step 4.

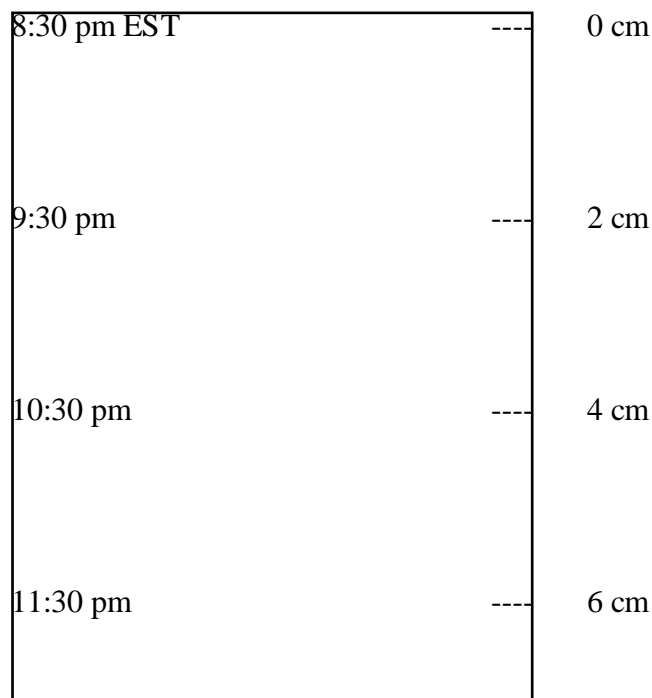
3. Check for comprehension and sort your students into working pairs. Distribute *Student Directions for Creating a Lunar Prospector Mission Timeline* to each pair of students. Have them turn to their computers and work on researching the timeline and converting times given.

Allow students to work on their own. Check their notes and time conversions for accuracy before demonstrating how to create a timeline.



4. Demonstrate how to create a timeline on 4 meters of adding machine tape. Measure off a dozen 2 cm sections and mark. Label the sections starting with 8:30 p.m. EST, 9:30 p.m., 10:30 p.m., etc. as shown below.

figure ? Example Timeline (not to scale)



From the 8:30 mark begin adding event labels in the appropriate locations. Start with **Launch 8:30**, add **Separation 9:38**, **Link to tracking station 9:48**, **rotate 10:08**, and **reduce spin 10:45**.

Allow students to work on their own.

5. When students have completed their timelines, display them on the chalkboard or bulletin board. Discuss any differences and similarities. Were they surprised by how much time elapsed during the trip from the Earth to the Moon? Why is it important to for scientists to plan out a timeline? How can timelines be useful tools for scientific work?

Explain that the next activity will include a chance for them to simulate the trip and orbit insertion. The simulated version will be much simpler with only two course corrections and one



insertion burn. They will not see the Prospector spinning or the Moon rotating.

Assessment

In this activity students demonstrated their ability to research, take notes, and possibly to convert times. They demonstrated their knowledge by creating a Mission Timeline. The accuracy of their work should be immediately apparent when they show you their notes and time conversions and again once they have completed their timelines.

Follow Up Activities

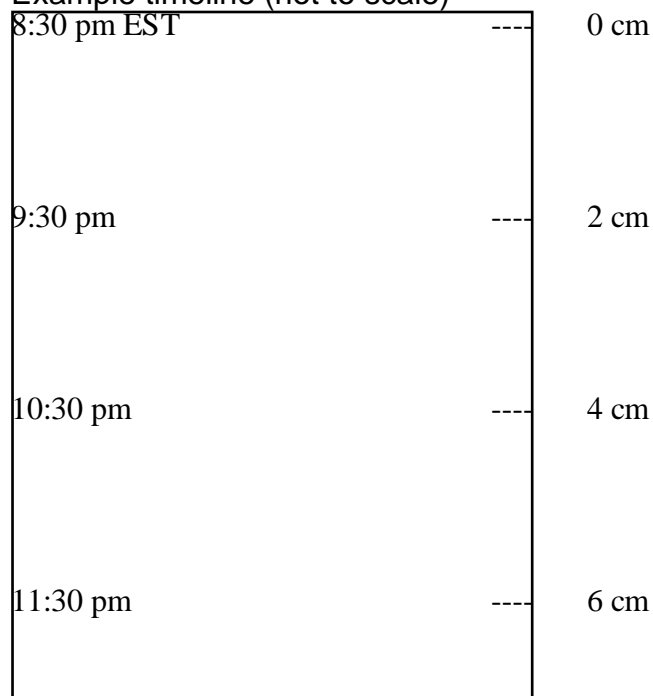
- Have students create timelines for other situations such as animal or insect lifecycles, personal history or a historical event.



Student Directions for Creating a Lunar Prospector Mission Timeline

1. Your assignment is to create a timeline of the Lunar Prospector's trip from the Earth to the Moon. Use the Student Resource Archive to learn more about the Lunar Prospector Mission Timeline. It will be helpful to take notes on the important times and events.
2. Once you have completed your notes on times and events, convert the times given to total elapsed time rather than time from Launch or from Separation.
3. Show your teacher the information you have collected about the Lunar Prospector Mission Timeline and your time conversions. Your teacher will give you the supplies you need to complete your timeline.
4. The scale for this timeline is 2 cm per hour, 48 cm per day. See the example below for an idea of how to prepare your timeline.

Example timeline (not to scale)



5. Now add in the important events from the trip from Earth to the Moon. Be sure you place them by or between the right times. You may want to add color to make the timeline more clear. For instance, each 24 hour period could be a different color so you could see at a glance how many days the journey takes.
-



Student Page - Lunar Prospector Mission Timeline

day	time	action	day #
Mon., Jan. 5	8:30 PM	launch	1
Mon., Jan. 5	8:43 PM	Burnout of Athena	1
Mon., Jan. 5	9:26 PM	TLI ignites	1
Mon., Jan. 5	9:27 PM	TLI Separation	1
Mon., Jan. 5	10:10 PM	rotation	1
Mon., Jan. 5	11:16 PM	booms extend	1
Tues., Jan. 6	1:27 AM	first flight-path correction	2
Tues., Jan. 6	11:06 PM	ER, NS, GRS finish degassing, collect data	2
Wed., Jan. 7	1:27 AM	second flight-path correction	3
Th., Jan. 8	1:27 AM	third flight-path correction	4
Th., Jan. 8	2:00 AM	spun up to 18 rpm, oriented for LOI	4
Fri., Jan. 9	7:58 PM	Moon's gravity stronger than Earth's	5
Sat., Jan. 10	5:43 AM	engines fire for LOI burn	6
Sun., Jan. 11	5:42 AM	second fire for LOI	7
Mon., Jan. 12	6:11 AM	third fire for LOI	8
Mon., Jan. 12	11:54 AM	communication switched to medium-gain antenna, data collection at Moon begins	8



Teacher Key - Lunar Prospector Mission Timeline

Timeline, first 8 days.

day	time	elapsed time	action	day #
Mon Jan 5	8:30 PM		launch	1
Mon Jan 5	8:43 PM	L+0:13	Burnout of Athena	1
Mon Jan 5	9:26 PM	L+0:56	TLI ignites	1
Mon Jan 5	9:27 PM	L+0:57	TLI Separation	1
Mon Jan 5	9:50 PM	S+0:23	link established	1
Mon Jan 5	10:10 PM	S+0:43	rotation	1
Mon Jan 5	10:32 PM	S+1:05	reduce spin	1
Mon Jan 5	10:43 PM	S+1:16	power to MAG, ER, GRS, and NS	1
Mon Jan 5	11:16 PM	S+1:49	booms extend	1
Tue Jan 6	12:32 AM	S+3:05	spin up to 12 rpm	2
Tue Jan 6	1:27 AM	S+4:00	first flight-path correction	2
Tue Jan 6	2:42 AM	S+5:15	APS turned on	2
Tue Jan 6	11:06 PM	S+1 day, 1:39 hrs	ER, NS, GRS finish degassing, collect data	2
Wed Jan 7	1:27 AM	S+1 day, 4:00 hrs	second flight-path correction	3
Thu Jan 8	1:27 AM	S+2 days, 4:00 hrs	third flight-path correction	4
Thu Jan 8	2:00 AM	S+2 days, 4:33 hrs	spun up to 18 rpm, oriented for LOI	4
Fri Jan 9	7:58 PM	S+3 days, 22:31 hrs	Moon's gravity stronger than Earth's	5
Sat Jan 10	5:43 AM	S+4 days, 8:16 hrs	engines fire for LOI burn	6
Sun Jan 11	5:42 AM	S+5 days, 8:15 hrs	second fire for LOI	7
Mon Jan 12	6:11 AM	S+6 days, 8:44 hrs	third fire for LOI	8
Mon Jan 12	9:25 AM	S+6 days, 11:58 hrs	engines fire to align craft to elliptic	8
Mon Jan 12	11:54 AM	S+6 days, 14:04 hrs	communication switched to medium-gain antenna, data collection at Moon begins	8



Activity Four - The Mission

Introduction

In this activity students have a chance to loosely apply the concept of controlling variables to the Lunar Prospector Simulation game The Mission. They will use the concept to achieve their mission of putting the Lunar Prospector into polar orbit around the Moon. Finally they will review what they learned over the duration of the unit and revise some of their original conceptions.

Objectives

- The students will be able to succeed at The Mission by “controlling” the variables of the game.
- The students will be able to discuss what they learned the Lunar Prospector Mission.

Key Details

Depending on your students' abilities and prior knowledge this activity should take:

- 4-10 minutes introduction and explanation
- 1-5 minutes demonstration
- 10-20 minutes for using software
- 5-15 minutes discussion

Total 20-50 minutes

Supplies

- chart papers from Activity One
- two blank sheets of chart paper
- markers and tape

Equipment

- display for computer output (LCD panel and Overhead Projector, large monitor, projector and screen)
- computers (center or lab set up) with Lunar Prospector CD installed or Website bookmarked

Preparation -- The Day Before

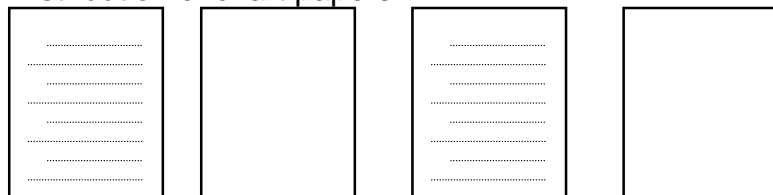
In your computer lab or center, check the Lunar Prospector CD or Exploring Space bookmark to be sure it is functioning.



Preparation -- Before the Activity

Hang the chart papers from Activity One at the front of the room alternating with the two blank papers.

Distribution of chart papers



Description of Activity

1. Briefly review the previous activity and introduce the current one. The students studied the destination, the spacecraft, and the trip. Now it is finally time to use The Mission to simulate sending the Lunar Prospector to the Moon. Most students have had a chance to experiment with The Mission section of the Lunar Prospector Simulation but few have had a successful voyage. Explain that you are going to borrow a principle of scientific investigation called controlling variables.
2. Explain that a variable is something that is changeable, or liable to vary in an experiment. Ask students to give examples of variables in experiments they have done or seen. For instance light, water, and soil mixtures are all variables in plant growth experiments. Ask students to state the variables from The Mission game: launch time, correction phases 1 and 2, and lunar orbital insertion burn. During a plant growth experiment, a scientist would control the variables by changing one at a time. For instance all plants would get the same soil treatment and same amount of water but different amounts of light. Controlling the variables in The Mission is a similar process. Settings for launch time and the length of the orbital insertion burn should remain set while correction phases 1 and 2 are adjusted (communication and battery status readings must be active). Once an accurate position for the correction phases is found, then the launch time can be adjusted. Finally the orbital insertion burn can be adjusted. These changes and adjustments should be recorded along with the result of each.

Optional: The order of variables to be controlled listed above is ideal for quick success. However, you may want your students to discover for themselves by experimenting. In this case



simply give them an example of controlling variables in an experimental setting, such as the plant growth example above, and allow them to extrapolate for themselves what would be appropriate in The Mission.

3. If necessary, project your computer screen output and demonstrate how to record the settings of the variables by playing one round of The Mission. Have students turn to their computers and allow time for them to work.
4. Have students share what they learned-- their conclusions and how they reached those conclusions. Did they find any clues in the text that helped them narrow down their choices?
5. Direct the student's attention to the chart papers from Activity One displayed at the front of the room. Give students a moment to read the first page describing what they already know about the Moon and how to get there. Ask what they would state differently, what they would change and what they learned. Record these ideas on the blank sheet of chart paper.

Review the second page regarding why scientists want more information about the Moon. Ask students what they would add to the new list or remove from the original list. Write their ideas on the fresh chart paper or cross off old ones from the original list.

Assessment

In this activity students demonstrated their knowledge by their involvement with The Mission game and by their contributions to the concluding discussion. If the students have been keeping a science journal or notebook or, if you desire a final evaluation, have them respond to a final statement or question.

Follow Up Activities

- Have students choose another destination within our solar system and plan mission.



Resource list

NASA Educational Websites

<http://lunar.arc.nasa.gov/>

<http://www.exploringspace.arc.nasa.gov/>

<http://spacelink.nasa.gov/.index.html>

<http://quest.arc.nasa.gov/>

NASA's On-line Educator Resource Centers

Ames Educator Resource Center

<http://ccf.arc.nasa.gov/dx/basket/trc/trchome.html>

The Educator Resource Center located at NASA Ames Research Center, Moffett Field, California, serves educators in the western states (Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming) and trust territories of the Pacific Islands.

NASA Lewis Teacher Resource Center Activities

http://www.lerc.nasa.gov/Other_Groups/K-12/TRC/TRCactivities.html

Choose from an array of Rocket or Aeronautic activities or try out the Looking at Earth from Space online glossary.

Stennis Space Center Educator Resource Center

<http://www.edu.ssc.nasa.gov/htmls/trc/trc.htm>

The Stennis ERC, located in the Visitor's Center, provides free services to educators including video tapes, computer software, slides, lesson plans, and other educational materials.

Goddard Space Flight Center's Educator Resource Center

<http://pao.gsfc.nasa.gov/gsfcc/educ/trl/welcome.html>

The Educator Resource Center at the Goddard Space Flight Center serves educators in the eleven northeastern states (Connecticut, Delaware, Maine,



Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont) and the District of Columbia.

Langley Research Center's Educator Resource Center
<http://www.vasc.org/homepg.html>

The NASA Langley Research Center (LaRC) established its Educator Resource Center (ERC) at the Virginia Air and Space Center in Hampton, Virginia. This online connection expands the reach of the ERC past Langley's five state region (which includes Virginia, West Virginia, North Carolina, South Carolina and Kentucky) to provide NASA resources and information around the globe through the World Wide Web.

Central Operation of Resources for Educators (CORE)

CORE was designed for the national and international distribution of NASA educational audio-visual materials.

CORE is a nonprofit institution which mails audiovisual materials at cost, plus shipping and handling, to U.S. and to international educators. An educator may request a catalogue and an order form from CORE by writing on school letterhead or by telephoning.

For more information, contact:
NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
(216) 774-1051, Ext. 293/294

Educator Resource Centers (ERCs) (as of June 1997)

Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

NASA Ames Research Center
Educator Resource Center
Mail Stop 253-2
Moffett Field, CA 94035-1000
Phone: (415) 604-3574
Fax: (415) 604-3445



For more information, contact:

Mr. Garth A. Hull
Chief, Educational Programs Branch
Mail Stop 204-12
NASA Ames Research Center
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Phone: (415) 604-5543
Fax: (415) 604-3953

California (Mainly cities near Dryden)

NASA Dryden Educator Resource Center
45108 North 3rd Street East
Lancaster, CA 93535
Phone: (805) 948-7347
Fax: (805) 948-7068

For more information, contact:

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For more information, contact:

California (Mainly cities near Vandenberg AFB)

Mr. Edmond Burke
Maple High School
Vandenberg Air Force Base
One Carob Street
NASA Educator Resource Center
Lompac, CA 93437
Phone: (805) 735-5131



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Virginia's and Maryland's Eastern Shores

GSFC/Wallops Flight Facility
Visitor Center
NASA Educator Resource Center
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Wallops Island, VA 23337
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Fax: (757) 824-1776

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*solar system and planetary exploration inquiries are handled.

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Pasadena, CA 91109
Phone: (818) 354-8251

Florida, Georgia, Puerto Rico, Virgin Islands

NASA John F. Kennedy Space Center
Educator Resource Center
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Kennedy Space Center, FL 32899-0001
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Fax: (407) 867-7242

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Kennedy Space Center, FL 32899-0001
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Colorado, Kansas, Nebraska, New Mexico, North Dakota, South Dakota, Texas

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Educator Resource Center
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NASA Educator Resource Center
Virginia Air and Space Center
Hampton Roads History Center
600 Settler's Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 ext. 757
Fax: (757) 727-0898

For more information, contact:
Dr. Marchelle Canright
Center Education Program Officer
Mail Stop 400
NASA Langley Research Center
Hampton, VA 23681-0001
Phone: (757) 864-3313



Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

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Cleveland, OH 44135-3191
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Fax: (601) 688-2824

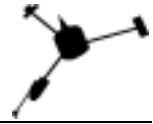
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Alabama, Arkansas, Iowa, Louisiana, Missouri, Tennessee

U. S. Space & Rocket Center
NASA Marshall Educator Resource Center
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Glossary

areology	scientific study of the history of Mars, as recorded in rocks
gamma ray	a type of high-energy radiation
highlands	heavily cratered light-colored regions of the lunar surface (the Moon's oldest rocks)
KREEP	an elemental composite material (used by scientists as a chemical tracer) consisting of <u>K</u> -potassium, <u>R</u> are <u>E</u> arth <u>E</u> lements, and <u>P</u> -Phosphorous
Lunar eclipse	period in which the Earth is positioned so as to obscure the Moon from sunlight
Lunar Orbit Insertion (LOI)	spacecraft slows down in order to be captured by the Moon's gravity (placing it into lunar orbit)
maria	smooth, dark regions of the lunar surface (the Moon's youngest rocks)
mascon	concentrations of mass on the lunar surface
outgassing	venting of gases from the lunar interior
regolith	a mixture of fine dust and rocky debris (produced by meteor impacts) covering the lunar surface
selenology	scientific study of the history of the Moon, as recorded in rocks